**Indicator: Primary Particulate Matter Emissions (008b)**

Particulate matter (PM) is the general term used to describe solid particles and liquid droplets found in the air. The composition and size of these airborne particles and droplets vary significantly: some particles are large enough to be seen as dust or dirt, while others are so small they can be seen only using a powerful microscope. Two size ranges, known as PM10 and PM2.5, are widely monitored, both at major emissions sources and in the ambient air. PM10 includes particles that have aerodynamic diameters less than or equal to 10 microns (µm), approximately equal to one-seventh the diameter of human hair. PM2.5 is the subset of PM10 particles that have aerodynamic diameters less than or equal to 2.5 µm. Particles within the two size ranges exhibit significantly different behavior in the atmosphere. PM2.5, or fine particles, can remain airborne for long time frames and travel hundreds of miles. Coarse particles, or the subset of PM10 that is larger than 2.5 µm, do not remain airborne as long and their spatial impact is typically limited because they tend to deposit to the ground in the downwind areas of emissions sources. Larger coarse particles are not readily transported across urban or broader areas because they are generally too large to follow air streams and they tend to be removed easily by impaction on surfaces. In short, as the particle size increases, the amount of time the particles remain airborne decreases. The indicator "Ambient Concentrations of PM" describes the way PM can harm human health and the environment (EPA 2004).

PM can be emitted directly or formed in the atmosphere. "Primary" particles refer to those that emissions sources release directly into the air. These include dust from roads and soot from combustion sources. In general, coarse PM is composed largely of primary particles. "Secondary" particles, on the other hand, are formed in the atmosphere from chemical reactions involving primary gaseous emissions; thus, these particles form at locations distant from the sources that release the precursor gases. Examples include sulfates formed from sulfur dioxide emissions from power plants and industrial facilities and nitrates formed from nitrogen oxides released from power plants, mobile sources, and other combustion sources. Unlike coarse PM, a much greater portion of fine PM (or PM2.5) contains secondary particles (EPA 2004).

This indicator tracks trends in annual average primary PM emissions data tracked by the National Emissions Inventory (NEI). For PM, the NEI tracks emission rate data, both measured and estimated, for primary particles only Because secondary particles are not released directly from stacks, the NEI instead tracks the precursors that contribute to formation of secondary particles. These precursors include nitrogen oxides (Indicator "Nitrogen Oxide Emissions") and sulfur dioxide (Indicator "Sulfur Dioxide Emissions"). The NEI is a composite of data from many different data sources including industry and numerous state, tribal, and local agencies. Different data sources use different data collection methods, and many of the emissions data are estimates rather than actual measurements. Emissions are tracked for stationary point and non-point sources as well as onroad and non-road mobile sources. NEI data have been collected since 1990 and cover all 50 states and their counties, D.C., the U.S. territories of Puerto Rico and Virgin Islands, and some of the territories of federally-recognized American Indian nations. Data are presented only for 1990 and the years from 1996 forward because although data are available for 1991 – 1995, they have not been updated and comparisons of these data with those from other inventory years could lead to incorrect trends assumptions. Inventory years 1990 and from 1996 forward are up to date.

**What the Data Show**

According to NEI data, national total PM10 emissions from anthropogenic sources (or sources of human origin), excluding wildfires and prescribed burnings, decreased by 6 percent between 1990 and 2002, from 3,215,903 to 3,011,406 tons (Figure 008b-1). National total PM2.5 emissions from anthropogenic sources (or sources of human origin), excluding wildfires and prescribed burnings, increased by 4 percent between 1990 and 2002, from 2,325,914 to 2,426,060 tons (Figure 008b-2).

The four source categories in the figures include: 1) "fuel combustion" which includes emissions from power plants, industrial, commercial and institutional sources as well as residential heaters and boilers, 2) "industrial and other processes" which includes large point sources such as refineries and smelters as well as smaller sources such as drycleaners and service stations, 3) "on road vehicles" which includes cars, trucks, buses, and motorcycles and 4) "non-road vehicles and engines" such as farm and construction equipment, lawnmowers, chainsaws, boats/ships, snowmobiles, aircraft, and others. In recent years, the largest source of PM emissions in both size categories has been fuel combustion followed by industrial and other processes.

Trends in PM10 and PM2.5 emissions varied across the ten EPA Regions between 1990 and 2002. Seven of the Regions showed a net decrease in PM10 emissions while the other three (Regions 3, 4, and 8) registered net increases, the most substantial being in Regions 3 and 4. PM2.5 emissions increased in half the Regions during the 1990-2002 period. Trends for PM2.5 were similar to those for PM10 with Regions 3 and 4 once again showing the greatest net increases.

**Indicator Limitations**

- Although PM emissions trends have been generated using well-established estimation methods, the data generally reflects estimates based on empirical and engineering models and not actual measurement of primary PM emissions. Some point sources have conducted testing for PM10 and PM2.5.
- The methodology for estimating emissions is continually reviewed and sometimes changes (e.g., the inclusion of "condensables" in 1999); emissions data presented in this indicator are organized into source categories and subsets of PM to minimize the extent to which methodological changes would bias the trend analyses.
- This indicator tracks only primary PM emissions, which do not account for formation of secondary particles from reactions involving precursor gases. Emissions relevant to secondary particle formation include nitrogen oxides (Indicator "Nitrogen Oxide Emissions") and sulfur dioxide (Indicator "Sulfur Dioxide Emissions").
- Not all states and local agencies-provide the same data or level of detail for a given year.

**Data Sources**

U.S. Environmental Protection Agency. National Emissions Inventory - http://www.epa.gov/ttn/chief/net/neidata.html

**References**

Interagency Monitoring of Protected Visual Environments Network and EPA Speciation Network, 2002

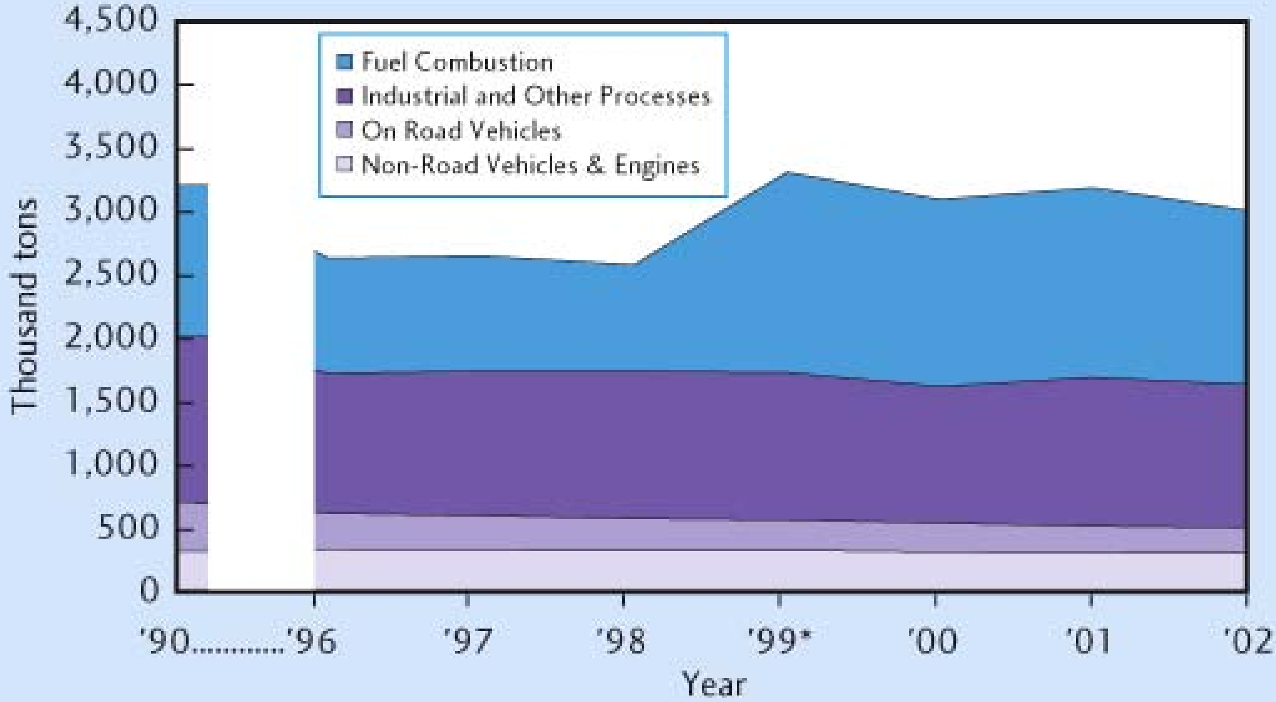
U.S. Environmental Protection Agency. 2003. Latest Findings on National Air Quality – 2002 Status and Trends, EPA 454/K-03-001. Research Triangle Park, NC; US Environmental Protection Agency, Office of Air Quality Planning and Standards, August 2003.

U.S. Environmental Protection Agency. 2003. National Air Quality and Emissions Trends Report - 2003 Special Studies Edition, EPA 454/R-03-005. Research Triangle Park, NC; US Environmental Protection Agency, Office of Air Quality Planning and Standards, September 2003.

U.S. Environmental Protection Agency. 2004. The Particle Pollution Report, EPA 454/R-04-002. Research Triangle Park, NC; US Environmental Protection Agency, Office of Air Quality Planning and Standards, December 2004.

**Graphics**

Figure 008b-1: National $PM_{10}$ emissions, 1990 and 1996-2002

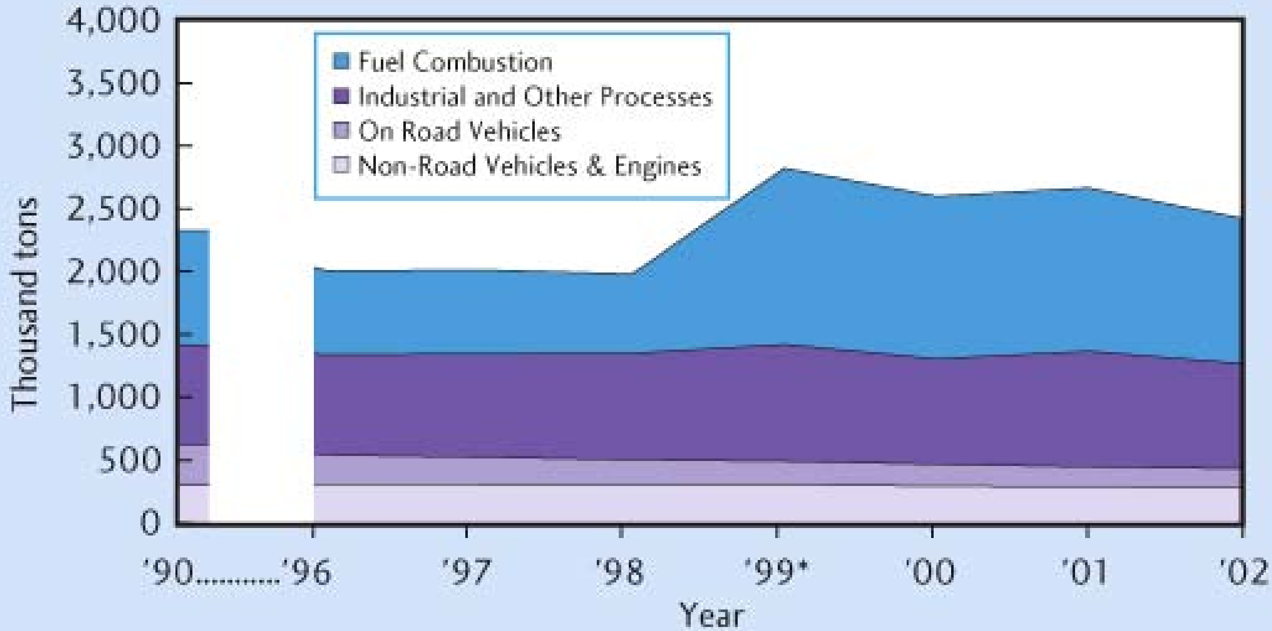



* Starting in 1999, the emission estimation methodology was changed to include emissions from "condensible" particulate matter.

Source: National Emissions Inventory (NEI).

Note: data are presented for 1990 and 1996-2002, as datasets from these inventory years are all fully up-to-date. Data are available for inventory years 1991–1995, but these data have not been updated to allow comparison with data from 1990 and 1996–2002.

# Figure 008b-2: National $PM_{2.5}$ emissions, 1990 and 1996-2002

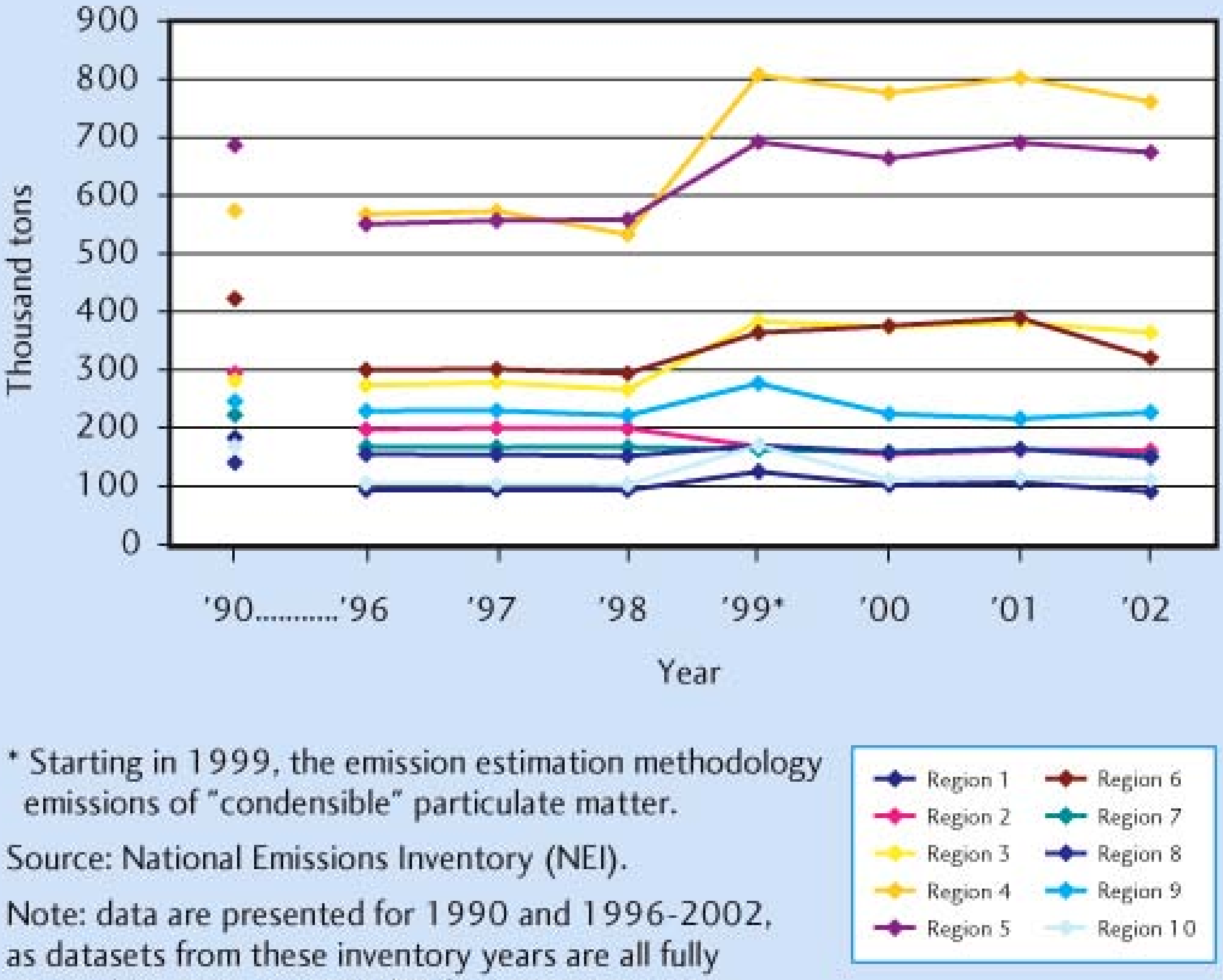



* Starting in 1999, the emission estimation methodology was changed to include emissions from "condensible" particulate matter.

Source: National Emissions Inventory (NEI).

Note: data are presented for 1990 and 1996–2002, as datasets from these inventory years are all fully up-to-date. Data are available for inventory years 1991–1995, but these data have not yet been updated to allow comparison with data from 1990 and 1996–2002.

# Figure 008b-3: $PM_{10}$ emissions by EPA region, 1990 and 1996-2002

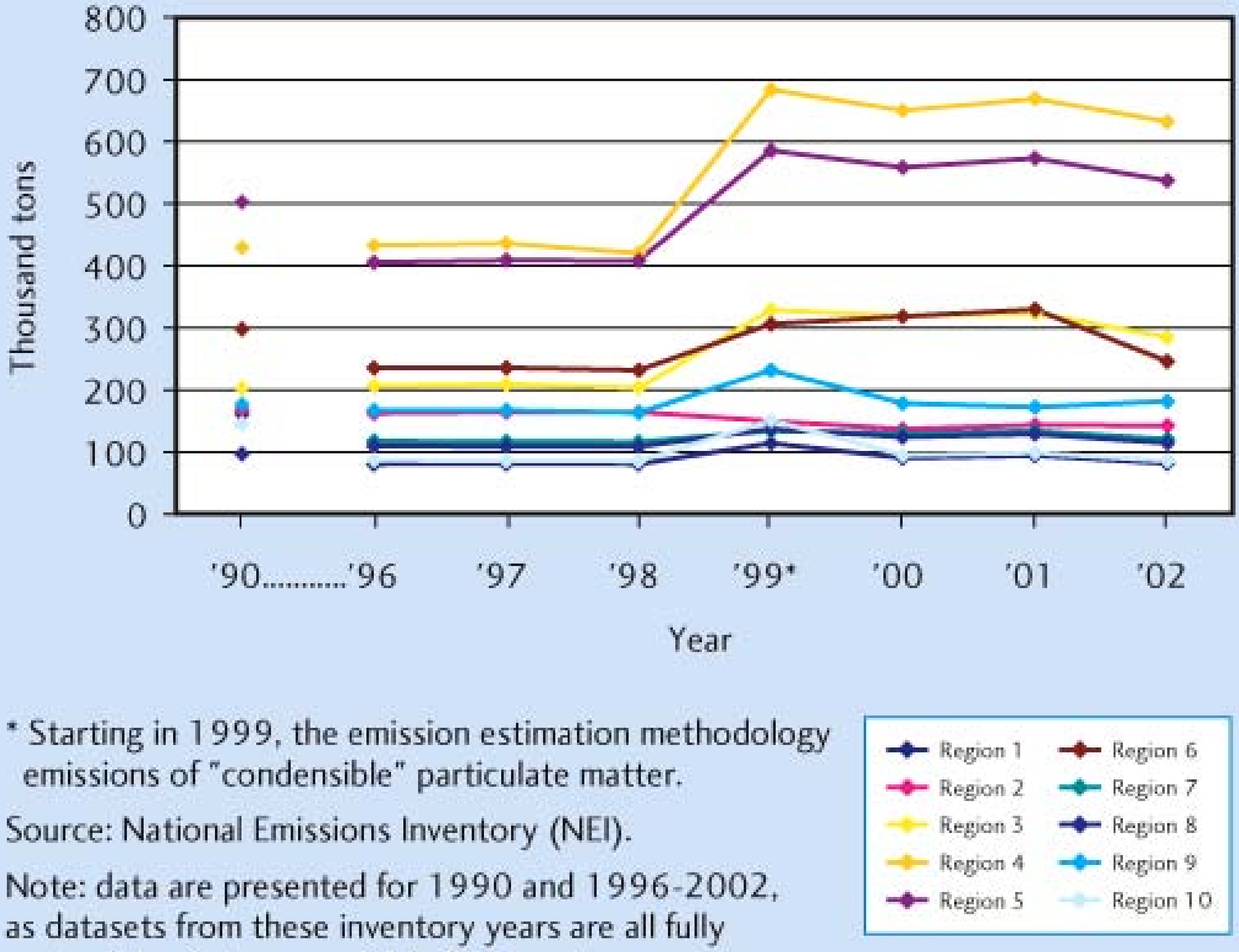



* Starting in 1999, the emission estimation methodology emissions of "condensible" particulate matter.

Source: National Emissions Inventory (NEI).

Note: data are presented for 1990 and 1996-2002, as datasets from these inventory years are all fully up-to-date. Data are available for inventory years 1991–1995, but these data have not been updated to allow comparison with data from 1990 and 1996–2002.

# Figure 008b-4: $PM_{2.5}$ emissions by EPA region, 1990 and 1996-2002




* Starting in 1999, the emission estimation methodology emissions of "condensible" particulate matter.

Source: National Emissions Inventory (NEI).

Note: data are presented for 1990 and 1996-2002, as datasets from these inventory years are all fully up-to-date. Data are available for inventory years 1991–1995, but these data have not been updated to allow comparison with data from 1990 and 1996–2002.

**R.O.E. Indicator QA/QC**

**Data Set Name:** PM EMISSIONS
**Indicator Number:** 008c (89082)
**Data Set Source:** EPA National Emissions Inventory
**Data Collection Date:** ongoing PM2.5 1999-pres pm10 1980-present
**Data Collection Frequency:** varies annually-triennially
**Data Set Description:** PM Emissions (PM2.5 & PM10)
**Primary ROE Question:** What are the trends in outdoor air quality and effects on human health and ecological systems?

**Question/Response**

**T1Q1** Are the physical, chemical, or biological measurements upon which this indicator is based widely accepted as scientifically and technically valid?

Yes. While the NEI is a composite of data from many different data sources and methods, most of which are estimates instead of actual measurements with associated precision and accuracy, the methods are widely accepted as technically valid. These methods are considered largely sufficient in their application to derive the indicator data and conclusions presented to the typical user of the ROE. The NEI contains annual emissions (units = tons/year) of the criteria pollutants and the hazardous air pollutants (HAPs) noted in the Clean Air Act Amendments of 1990 (CAAA). The methods used to develop the NEI pollutant data vary by source sector and involve multiple data sources. A general description of methods by source sector is included below. Source emissions can be measured using monitoring equipment or estimated by using emission factors and emission process activity levels. Mathematical models may be used to characterize and simulate emissions that are influenced by several variables. For most source types, estimation techniques are the most practical. The NEI emissions are grouped into four main source sectors: Point sources and NonPoint sources (these are also referred to as stationary sources) and Onroad Mobile and Nonroad mobile sources (these are referred to as mobile sources). The Point source sector contains data on individual industrial, commercial and institutional facilities and is further divided into two subsectors: Electric Generating Units (EGUs) and NonEGUs. For the NEI sector data that is collected from state and local agencies - they either gather the data from their facilities or estimate the emissions themselves, using average and industry-specific emission factors. Some of the techniques they may use to generate their point and nonpoint estimates are referenced in a guidebook of methods which is endorsed by the EPA and the state and local agencies (STAPPA/ALAPCO). The guidebook of methods is located on http://www.epa.gov/ttn/chief/eiip/techreport/. Depending on the source sector and the pollutants of interest, the EPA uses other data sources in addition to the data received by the state and local agencies. Those other data sources, where applicable, are generally described below by sector, and identified specifically in the EPA s Preparation Plan for the 2002 NEI, located on http://www.epa.gov/ttn/chief/net/2002inventory.html. In addition to identifying the data sources, the NEI 2002 Preparation Plan also describes the EPA's current method of quality checking the different data sources, and blending and merging among them, as well as augmenting data in order to complete the data set over space and time for specific source sectors and pollutants. The EPA Preparation Plan for the 1999 NEI (http://www.epa.gov/ttn/chief/net/nei_plan_feb2001.pdf) describes the data sources and process used to compile the 1999 HAP data which is included in the indicator. There is a triennial development effort and focus on compiling data for the NEI which results in the most complete national emissions inventory data every third year. For the criteria emissions in the NEI, data is also developed for the years in between the 3-year inventory cycles. For some sectors and pollutants, the methods used may be the same as those applied for the 3-year inventory, or the data may be extrapolated from the most recent third year inventory using economic projections or more simply as a mathematical interpolation between previous and subsequent years of record. While the NEI is a composite of data from many different data sources and methods, most of which are estimates instead of actual measurements with associated precision and accuracy, the methods are widely accepted as technically valid. These methods are considered largely sufficient in their application to derive the indicator data and conclusions presented to the typical user of the ROE.

**T1Q2** Is the sampling design and/or monitoring plan used to collect the data over time and space based on sound scientific principles?

There is not a sampling design per se for the overall NEI data development project, at least not in the typical terms of a statistical sampling design. The data methods are predominantly based on estimation techniques rather than measurement techniques with associated precision and accuracy and standard error. For most sector data, emission factors are used with average emission process rates and average activity indicators to estimate typical emissions expected from similar processes in different geographical areas. Emission factors typically are based on emission testing or other sampling observations of sources and are generally developed and revised as need arises and more data becomes available. Highway vehicle emissions factors, however, are based on relatively recent research-driven sampling approaches that are documented in information collection plans implemented by the EPA s Office and Transportation and Air Quality Planning (http://www.epa.gov/otaq/ap42.htm). For onroad mobile sources, estimates are made by month or by season to account for typical temperatures and fuel properties. Estimates of vehicle miles traveled are based on the United States Department of Transportation (US DOT) Highway Performance Monitoring System, which makes use of a formal sample panel of roadway segments. Like onroad mobile sources, emissions from some other processes are estimated for time periods less than annual. As an example, pollutant emissions for seasonal processes are estimated for only a portion of the year in which they occur (i.e., winter burning season). The NEI attempts to capture the full universe of large point source facilities, which are closely monitored and located individually by the state and local agencies. Most Point EGU emissions are individually measured with continuous monitoring devices. These data are summarized to annual average emissions for all 50 states and their counties, D.C., the U.S. territories of Puerto Rico and Virgin Islands, and as available, for some of the territories of federally-recognized American Indian nations, and are widely used and accepted as an indicator of national and regional emission trends over time.

**T1Q3** Is the conceptual model used to transform these measurements into an indicator widely accepted as a scientifically sound representation of the phenomenon it indicates?

The annual emissions are directly estimated in most cases, or are simply totaled from monthly or seasonal estimates - there is no transformation.

**T2Q1** To what extent is the indicator sampling design and monitoring plan appropriate for answering the relevant question in the ROE?

The NEI is designed to explicitly answer the question posed in the ROE. This indicator estimates emissions from all anthropogenic sources of a primary air pollutant.

**T2Q2** To what extent does the sampling design represent sensitive populations or ecosystems?

The emission estimates that comprise the NEI are non-specific for sensitive populations or ecosystems. Rather, the data are specific for types of emission processes and as such, are representative of how much and where those process emissions occur by county for the nonpoint sources and by individual facility location for the point sources.

**T2Q3** Are there established reference points, thresholds or ranges of values for this indicator that unambiguously reflect the state of the environment?

This indicator(s) directly addresses changes in air pollutant emissions from year-to-year and the contributions of various types of emissions sources, by county, and for every state. Air pollutant emissions are a reliable gauge of impact on the environment and when considered along with air quality transport and transformation issues, are the foundation for air quality analysis, including health indicators. Emission reductions generally indicate positive impact on air quality. Average annual pollutant emission trends over time may also reference a specific year or years in the time series, during which emission reductions were realized due to previous year implementation of federal, regional, or local control and compliance programs. There are no thresholds or ranges of values associated with safe levels of emissions for this indicator.

**T3Q1** What documentation clearly and completely describes the underlying sampling and analytical procedures used?

The NEI is a composite of many data sources, much of which is provided by state and local agencies and comes to EPA with little or no documentation on the specific methods used to generate the estimates. An emission inventory guidebook of methods, which is endorsed by the EPA and the state and local agencies (STAPPA/ALAPCO), is generally used by state and local agencies as reference for acceptable methods. The guidebook of methods is located on http://www.epa.gov/ttn/chief/eiip/techreport/. For emissions that are reported by the states as direct measurements from monitoring devices, the analytical procedures are referenced on http://www.epa.gov/ttn/emc/. Documentation of the procedures that EPA used to compile the NEI data for some of the more recent years in the time series is located on http://www.epa.gov/ttn/chief/net/neidata.html and is more organized and descriptive than documentation for previous year data. Documentation for the earlier years noted in the time series is located on http://www.epa.gov/ttn/chief/trends/procedures/neiproc99.pdf. Some of the methods noted have subsequently been revised for specific processes and years as EPA has gone back to update and apply improved methods. The documentation sources noted above will also describe use of emission factors. Documentation on process specific emission factors and how they were derived is located on http://www.epa.gov/ttn/chief/ap42/index.html.

**T3Q2** Is the complete data set accessible, including metadata, data-dictionaries and embedded definitions or are there confidentiality issues that may limit accessibility to the complete data set?

The national annual NEI criteria emission trends summaries, as presented in the indicator, are publicly available on http://www.epa.gov/airtrends/econ-emissions.html. The national annual NEI hazardous air pollutant (HAP) data for year 1999, as presented in the indicator, are publicly available on http://www.epa.gov/air/data/index.html. Data format information typically resides at the same location as the data itself.

**T3Q3** Are the descriptions of the study or survey design clear, complete and sufficient to enable the study or survey to be reproduced?

The EPA's documentation (see that noted in T3Q1) of how the NEI data estimates are generated will facilitate reproduction of some emission process estimates. As the EPA's documentation has evolved and improved over the years, it is expected that the more recent data years are documented in a more organized and transparent manner and would best enable reproducibility of emission estimates. Where EPA's documentation for specific years indicates that data was incorporated as that received from the state and local agencies, there is no additional documentation available by which to reproduce the state-derived values.

**T3Q4** To what extent are the procedures for quality assurance and quality control of the data documented and accessible?

Much of the data that is used to compile the NEI is gathered indirectly from multiple and numerous sources, as referenced in the estimation methods information under T1Q1. These indirect data sources are presumed to have their own QA practices. Where state-supplied emissions estimates are used for some sectors and pollutants, it is presumed that states have QA plans in most cases but EPA does not systematically obtain information on QA practices from the states. The EPA contractors who use data sources and EPA-developed emissions factors to make emissions estimates operate under general contract-wide quality assurance plans, which can be made available on request. In addition, the EPA's more recent QC practices performed during the blending and merging of data from numerous sources, are described in the 2002 NEI Preparation Plan located on http://www.epa.gov/ttn/chief/net/2002inventory.html.

**T4Q1** Have appropriate statistical methods been used to generalize or portray data beyond the time or spatial locations where measurements were made (e.g., statistical survey inference, no generalization is possible)?

No statistical generalization is performed to generate the national annual emissions trends presented in the indicator. The annual pollutant totals are developed at the plant or county level and then simply totaled and summarized at the regional and national levels.

**T4Q2** Are uncertainty measurements or estimates available for the indicator and/or the underlying data set?

No. At present, statistical uncertainty measures are not available for the underlying data that comprise the indicator. Most of the QA routines that are currently performed by EPA are sector data comparisons between different years or geographic areas, rather than on individual data variables. Much of the associated data variables for a specific sector are implied or not highly characterized, and therefore do not lend themselves well at present to quantitative uncertainty analysis.

**T4Q3** Do the uncertainty and variability impact the conclusions that can be inferred from the data and the utility of the indicator?

Yes, OAQPS has developed standardized procedures for quality assuring the NEI as discussed in the "2002 NEI Preparation Plan" (http://www.epa.gov/ttn/chief/net/2002neiplan_081004final.pdf). The procedures include use of software to facilitate and standardize review of the data by EPA regional offices and state, local and tribal agencies. During the review process, industries often closely review their emission estimates to ensure they have been correctly incorporated in the NEI. In addition, OAQPS is able to use techniques which contrast data from various sources and from several inventory years to understand variability and identify areas in need of additional review. Where several data sources are available, assessments of data quality are conducted by OAQPS to ensure use of the highest quality emissions data when developing the NEI. The sum of the review procedures used for developing the NEI is believed to yield data of sufficient quality to support the conclusions which typical users will derive from the indicators. However, for the most rigorous applications, the NEI may be used in conjunction with ambient monitoring data and air quality and source receptor models to better characterize air quality problems and thus reduce uncertainties.

**T4Q4** Are there limitations, or gaps in the data that may mislead a user about fundamental trends in the indicator over space or time period for which data are available?

The indicator represents aggregated data. Most of the data is the result of a calculation that combines an emission rate per unit of input or output and a measure of that input or output, rather than a direct measurement of emissions. All states and counties are represented in the NEI, however not all states and local agencies may provide the same data or level of detail for a given year. State and local agencies may prioritize their data development efforts on emissions in county and metropolitan areas that are nonattainment for specific ambient air quality standards, i.e., ozone or PM2.5 NAAQS. The result may be more complete and quality assured data submissions to the NEI for these areas. Where data is absent or incomplete, EPA performs some data extrapolation from previous year data or other data sources. Inference follows many processes, depending on source type, etc. To the extent possible, facility-specific or county-specific information is used. In some cases, all counties in a state are assumed to have common properties influencing emissions, for example daily low and high temperatures. Best available or at most plausible substitutes are used where needed. For example, gasoline fuel properties are not available for all counties, known fuel properties in nearby counties subject to similar regulations on gasoline are used instead. Various and not fully consistent methodologies have been used to develop the emission estimates in the NEI. This is to be expected considering the variety of organizations that have contributed the estimates.